

**Exhibit A**  
**SCOPE OF WORK**

**TECHNICAL TASK LIST**

<b>Task #</b>	<b>CPR</b>	<b>Task Name</b>
1	N/A	Administration
2		Advanced Combined Cooling Heat And Power For Building Efficiency
3		Solar Thermal For Efficient Combined Cooling, Heat, And Power
4		Improving Heating/Cooling Systems With Phase Change Materials
5		Mini-Channel Technology To Improve Solar Water Heaters
6		Wireless Measurement Tools For Better Indoor Environments
7		Saving Energy In Buildings With Adaptive Lighting Systems
8		Saving Energy In Buildings With Adaptive Envelope Systems
9		Improved HVAC Through Standards For Technician Instruments
10		Improving HVAC Electric Motor Systems In Buildings
11		Enabling Renewable Fuels Through Flexible Burners
12		Increasing Renewable Energy By Almond Shell Gasification

**KEY NAME LIST**

<b>Task #</b>	<b>Key Personnel</b>	<b>Key Subcontractor(s)</b>	<b>Key Partner(s)</b>
1	None		
2	Scott Samuelson		
3	Carl Blumstein	California Polytechnic State University San Luis Obispo	
4	Mark Modera		
5	Gerardo Diaz		
6	Ed Arens, Tom Webster		
7	Michael Siminovitch,		
8	Konstantinos Papamichael		
9	Kristin Heinemeier		
10	Sadru Ula,		
11	Vincent McDonnell		
12	Robert Cattolica, Bryan Jenkins		

## GLOSSARY

*Specific terms and acronyms used throughout this work statement are defined as follows:*

Acronym	Definition
AB-32	Assembly Bill 32
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CARB	California Air Resources Board
Cal Poly	California Polytechnic State University San Luis Obispo
CCHP	Combined Cooling, Heat and Power
CIEE	California Institute for Energy and Environment
CHP	Combined Heat and Power
CO	Carbon Monoxide
CSP	Concentrating Solar Power
CSP/NG	Concentrating Solar Power/Natural Gas System
CPR	Critical Project Review
Energy Commission	California Energy Commission
CPUC	California Public Utilities Commission
HTIL	HVAC Technician Instrument Laboratory
HVAC	Heating, Ventilating, and Air Conditioning
kW	Kilowatt
IEPR	Integrated Energy Policy Report
MW	Megawatt
NO <sub>x</sub>	Nitrogen Oxides
PAC	Project Advisory Committee
PCM	Phase Change Materials
PIER	Public Interest Energy Research
PMP	Performance Management Protocols
POX	Partial Oxidation
UCB	The Regents of the University of California, Berkeley
UCD	The Regents of the University of California, Davis
UCI	The Regents of the University of California, Irvine
UCM	The Regents of the University of California, Merced
UCR	The Regents of the University of California, Riverside
VFD	Variable Frequency Drive

## Problem Statement

California has enacted the Global Warming Solutions Act of 2006 (also known as AB-32). In support of this law, the California Public Utilities Commission (CPUC), in coordination with the California Energy Commission (Energy Commission) and the California Air Resources Board (CARB), has developed the California Long Term Energy Efficiency Strategic Plan. The plan calls for major reductions in greenhouse gas emissions related to California buildings and industry. Because facility occupants

require a reasonable level of indoor environmental quality, these reductions will require a major improvement in energy efficiency. Research and technological development is needed to meet these goals.

According to the Energy Commission's Integrated Energy Policy Report (IEPR), the first element in the state's loading order for meeting electricity needs is energy efficiency. In the Energy Commission's Natural Gas Program Plan, this goal is extended to natural gas. The primary goal of the Natural Gas Research Program is to provide affordable, comfortable and energy smart choices for daily life and a strong California economy, by addressing energy efficiency for utility operations, the food services sector, and natural gas driven heating, cooling, power, and hot water systems in residential and commercial buildings. Well-designed energy efficiency programs can reduce energy dependence, make business more competitive, and allow consumers to save money and live more comfortably.

### **Goals of the Agreement**

The goals of the agreement focus on seven areas:

- Improve energy performance of facilities by increasing use of Combined Heat and Power (CHP) and Combined Cooling, Heat and Power (CCHP) systems that leverage renewable resources as supplemental input along with natural gas.
- Reduce use of natural gas for residential hot water generation and distribution by improving thermal energy efficiency and cost effectiveness of solar water heaters and by developing improved residential hydronic heating technology for use in floor systems, radiators, fan coil units and fin-tube baseboard convectors.
- Increase use of renewably-produced and other available fuel gases in industrial and institutional applications.
- Reduce electric use in lighting systems by developing adaptive lighting and envelope technologies which maximize use of available natural lighting and automatically reduce electric lighting use when not needed.
- Improve indoor environments by developing technology to objectively measure indoor environmental parameters.
- Reduce the demand for electricity by improving the performance and specification of Heating, Ventilating, and Air- Conditioning (HVAC) drive motors.
- Improve small HVAC system performance by developing specifications for technician's instruments and promoting proper methods of use.

### **Objectives of the Agreement**

- Optimize and document the operation of novel integrated natural gas powered fuel cell, absorption chiller, and solar powered combined cooling heat and power (CCHP) system for commercial buildings.
- Document issues and challenges of deploying and commissioning a 100-1000 kilowatt (kW) CCHP system combining concentrated solar power with natural gas inputs, steam turbine electric generator, absorption cooling, and hot water generation for on-site institutional use.

- Research and document the feasibility of increasing the energy efficiency of residential heating systems by adding encapsulated phase change material into a closed water circulation system for both cooling and heating.
- Design and manufacture a mini-channel based solar water heater and demonstrate its improved energy performance with respect to a standard round-tube flat-plate solar water heater.
- Develop and publish designs and specifications for wireless toolkits to efficiently measure and record multiple indoor environmental variables. This will implement the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Performance Measurement Protocol and provide information enabling reduced energy use and improved indoor environmental quality.
- Develop and field test adaptive lighting systems for retail buildings in order to improve energy efficiency. These lighting systems will ensure lights are off or dimmed when no occupants are present or when there is available daylight.
- Develop and field test adaptive envelope systems for retail buildings in order to improve energy efficiency. These systems, such as automatic shading for windows and skylights, can adapt to environmental conditions in order to improve indoor environments and reduce energy use.
- Develop and publicize instrument specifications and instructions for their proper use by technicians to better install, repair and maintain HVAC equipment.
- Measure energy use on-site and under actual operating conditions of large motors in buildings, analyze current methods of specification, and develop and promote best engineering practices for testing and specifying these motors.
- Develop metrics for 'opportunity' fuels which can be used to augment or replace natural gas. Investigate combustion control systems in a prototype fuel-flexible boiler to develop settings suited to the combustion characteristics of fuels and fuel mixtures. Publicize and promote standards based on these studies.
- Optimize the gasification of almond shell biomass, improve gas cleanup, and reduce exhaust emissions. This will facilitate the use of the resulting fuel gas in combined heat and power agricultural applications, replacing natural gas.

## **TASK 1.0 ADMINISTRATION**

### **MEETINGS**

#### **Task 1.1 Attend Kick-off Meeting**

The goal of this task is to establish the lines of communication and procedures for implementing this Agreement.

#### **The Contractor shall:**

- Attend a "kick-off" meeting with the Energy Commission Contract Manager, the Contracts Officer, and a representative of the Accounting Office. The Contractor shall bring their Project Manager, Contracts Administrator, Accounting Officer, and others designated by the Energy Commission Contract Manager to this meeting. The administrative and technical aspects of this Agreement will be discussed at the

meeting. Prior to the kick-off meeting, the Energy Commission Contract Manager will provide an agenda to all potential meeting participants.

The administrative portion of the meeting shall include, but not be limited to, the following:

- Terms and conditions of the Agreement
- CPRs (Task 1.2)
- Match fund documentation (Task 1.7)
- Permit documentation (Task 1.8)

The technical portion of the meeting shall include, but not be limited to, the following:

- The Energy Commission Contract Manager's expectations for accomplishing tasks described in the Scope of Work;
- An updated Schedule of Deliverables
- Progress Reports (Task 1.4)
- Technical Deliverables (Task 1.5)
- Final Report (Task 1.6)

The Energy Commission Contract Manager shall designate the date and location of this meeting.

**Contractor Deliverables:**

- An Updated Schedule of Deliverables
- An Updated List of Match Funds
- An Updated List of Permits

**Energy Commission Contract Manager Deliverables:**

- Final Report Instructions

**Task 1.2 CPR Meetings**

The goal of this task is to determine if the project should continue to receive Energy Commission funding to complete this Agreement and if it should, are there any modifications that need to be made to the tasks, deliverables, schedule or budget.

Critical Project Reviews (CPR) provide the opportunity for frank discussions between the Energy Commission and the Contractor. CPRs generally take place at key, predetermined points in the Agreement, as determined by the Energy Commission Contract Manager and as shown in the Technical Task List above and in the Schedule of Deliverables. However, the Energy Commission Contract Manager may schedule additional CPRs as necessary, and, if necessary, the budget will be reallocated to cover the additional costs borne by the Contractor, but the overall contract amount will not increase.

Participants include the Energy Commission Contract Manager and the Contractor, and may include the Energy Commission Contracts Officer, the PIER Program Team Lead, other Energy Commission staff and Management as well as other individuals selected

by the Energy Commission Contract Manager to provide support to the Energy Commission.

**The Energy Commission Contract Manager shall:**

- Determine the location, date and time of each CPR meeting with the Contractor. These meetings generally take place at the Energy Commission, but they may take place at another location.
- Send the Contractor the agenda and a list of expected participants in advance of each CPR. If applicable, the agenda shall include a discussion on both match funding and permits.
- Conduct and make a record of each CPR meeting. One of the outcomes of this meeting will be a schedule for providing the written determination described below.
- Determine whether to continue the project, and if continuing, whether or not to modify the tasks, schedule, deliverables and budget for the remainder of the Agreement, including not proceeding with one or more tasks. If the Energy Commission Contract Manager concludes that the project needs a formal amendment or that satisfactory progress is not being made and the project needs to be ended, these conclusions will be referred to the Energy Commission's Research, Development and Demonstration Policy Committee for its concurrence.
- Provide the Contractor with a written determination in accordance with the schedule. The written response may include a requirement for the Contractor to revise one or more deliverable(s) that were included in the CPR.

**The Contractor shall:**

- Prepare a CPR Report for each CPR that discusses the progress of the Agreement toward achieving its goals and objectives. This report shall include recommendations and conclusions regarding continued work of the projects. This report shall be submitted along with any other deliverables identified in this Scope of Work. Submit these documents to the Energy Commission Contract Manager and any other designated reviewers at least 15 working days in advance of each CPR meeting.
- Present the required information at each CPR meeting and participate in a discussion about the Agreement.

**Contractor Deliverables:**

- CPR Report(s)
- CPR deliverables identified in the Scope of Work

**Energy Commission Contract Manager Deliverables:**

- Agenda and a List of Expected Participants
- Schedule for Written Determination
- Written Determination

### **Task 1.3 Final Meeting**

The goal of this task is to closeout this Agreement.

#### **The Contractor shall:**

- Meet with the Energy Commission to present the findings, conclusions, and recommendations. The final meeting must be completed during the closeout of this Agreement.

This meeting will be attended by, at a minimum, the Contractor, the Energy Commission Contracts Officer, and the Energy Commission Contract Manager. The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be two separate meetings at the discretion of the Energy Commission Contract Manager.

The technical portion of the meeting shall present findings, conclusions, and recommended next steps (if any) for the Agreement. The Energy Commission Contract Manager will determine the appropriate meeting participants.

The administrative portion of the meeting shall be a discussion with the Energy Commission Contract Manager and the Contracts Officer about the following Agreement closeout items:

- What to do with any state-owned equipment (Options)
  - Need to file UCC.1 form re: Energy Commission's interest in patented technology
  - Energy Commission's request for specific "generated" data (not already provided in Agreement deliverables)
  - Need to document Contractor's disclosure of "subject inventions" developed under the Agreement
  - "Surviving" Agreement provisions, such as repayment provisions and confidential deliverables
  - Final invoicing and release of retention
- Prepare a schedule for completing the closeout activities for this Agreement.

#### **Deliverables:**

- Written documentation of meeting agreements and all pertinent information
- Schedule for completing closeout activities

### **REPORTING**

**See Exhibit D, Reports/Deliverables/Records.**

#### **Task 1.4 Quarterly Progress Reports**

The goal of this task is to periodically verify that satisfactory and continued progress is made towards achieving the research objectives of this Agreement.

##### **The Contractor shall:**

- Prepare progress reports which summarize all Agreement activities conducted by the Contractor for the reporting period, including an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. Each progress report is due to the Energy Commission Contract Manager within 10 working days after the end of the reporting period. Attachment A-2, Progress Report Format, provides the recommended specifications.

##### **Deliverables:**

- Quarterly Progress Reports

#### **Task 1.5 Test Plans, Technical Reports and Interim Deliverables**

The goal of this task is to set forth the general requirements for submitting test plans, technical reports and other interim deliverables, unless described differently in the Technical Tasks. When creating these deliverables, the Contractor shall use and follow, unless otherwise instructed in writing by the Energy Commission Contract Manager, the latest version of the PIER Style Manual published on the Energy Commission's web site:

<http://www.energy.ca.gov/contracts/pier/contractors/index.html>

##### **The Contractor shall:**

- Unless otherwise directed in this Scope of Work, submit a draft of each deliverable listed in the Technical Tasks to the Energy Commission Contract Manager for review and comment in accordance with the approved Schedule of Deliverables. The Energy Commission Contract Manager will provide written comments back to the Contractor on the draft deliverable within 10 working days of receipt. Once agreement has been reached on the draft, the Contractor shall submit the final deliverable to the Energy Commission Contract Manager. The Energy Commission Contract Manager shall provide written approval of the final deliverable within 5 working days of receipt. Key elements from this deliverable shall be included in the Final Report for this project.

#### **Task 1.6 Final Report**

The goal of this task is to prepare a comprehensive written Final Report that describes the original purpose, approach, results and conclusions of the work done under this Agreement. The Energy Commission Contract Manager will review and approve the Final Report. The Final Report must be completed on or before the termination date of



the Agreement. When creating these deliverables, the Contractor shall use and follow, unless otherwise instructed in writing by the Energy Commission Contract Manager, the latest version of the PIER Style Manual published on the Energy Commission's web site:

<http://www.energy.ca.gov/contracts/pier/contractors/index.html>

The Final Report shall be a public document. If the Contractor has obtained confidential status from the Energy Commission and will be preparing a confidential version of the Final Report as well, the Contractor shall perform the following subtasks for both the public and confidential versions of the Final Report.

### **Task 1.6.1 Final Report Outline**

#### **The Contractor shall:**

- Prepare a draft outline of the Final Report.
- Submit the draft outline of Final Report to the Energy Commission Contract Manager for review and approval. The Energy Commission Contract Manager will provide written comments back to the Contractor on the draft outline within 10 working days of receipt. Once agreement has been reached on the draft, the Contractor shall submit the final outline to the Energy Commission Contract Manager. The Energy Commission Contract Manager shall provide written approval of the final outline within 5 working days of receipt.

#### **Deliverables:**

- Draft Outline of the Final Report
- Final Outline of the Final Report

### **Task 1.6.2 Final Report**

#### **The Contractor shall:**

- Prepare the draft Final Report for this Agreement in accordance with the approved outline.
- Submit the draft Final Report to the Energy Commission Contract Manager for review and comment. The Energy Commission Contract Manager will provide written comments within 10 working days of receipt.

Once agreement on the draft Final Report has been reached, the Energy Commission Contract Manager shall forward the electronic version of this report for Energy Commission internal approval. Once the approval is given, the Energy Commission Contract Manager shall provide written approval to the Contractor within 5 working days.

- Submit one bound copy of the Final Report with the final invoice.

**Deliverables:**

- Draft Final Report
- Final Report

**MATCH FUNDS, PERMITS, AND ELECTRONIC FILE FORMAT**

**Task 1.7 Identify and Obtain Matching Funds**

The goal of this task is to ensure that the match funds planned for this Agreement are obtained for and applied to this Agreement during the term of this Agreement.

The costs to obtain and document match fund commitments are not reimbursable through this Agreement. While the PIER budget for this task will be zero dollars, the Contractor may utilize match funds for this task. Match funds shall be spent concurrently or in advance of PIER funds during the term of this Agreement. Match funds must be identified in writing, and the associated commitments obtained before the Contractor can incur any costs for which the Contractor will request reimbursement.

**The Contractor shall:**

- Prepare a letter documenting the match funding committed to this Agreement and submit it to the Energy Commission Contract Manager at least 2 working days prior to the kick-off meeting:
  1. If no match funds were part of the proposal that led to the Energy Commission awarding this Agreement and none have been identified at the time this Agreement starts, then state such in the letter.
  2. If match funds were a part of the proposal that led to the Energy Commission awarding this Agreement, then provide in the letter:
    - A list of the match funds that identifies the:
      - Amount of each cash match fund, its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied.
      - Amount of each in-kind contribution, a description, documented market or book value, and its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Contractor shall identify its owner and provide a contact name, address and telephone number, and the address where the property is located.

- A copy of the letter of commitment from an authorized representative of each source of cash match funding or in-kind contributions that these funds or contributions have been secured.
- Discuss match funds and the implications to the Agreement if they are significantly reduced or not obtained as committed, at the kick-off meeting. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide the appropriate information to the Energy Commission Contract Manager if during the course of the Agreement additional match funds are received.
- Notify the Energy Commission Contract Manager within 10 working days if during the course of the Agreement existing match funds are reduced. Reduction in match funds may trigger an additional CPR.

**Deliverables:**

- A letter regarding Match Funds or stating that no Match Funds are provided
- Letter(s) for New Match Funds
- A copy of each Match Fund commitment letter
- Letter that Match Funds were Reduced (if applicable)

**Task 1.8 Identify and Obtain Required Permits**

The goal of this task is to obtain all permits required for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track.

Permit costs and the expenses associated with obtaining permits are reimbursable under this Agreement. Permits must be identified in writing before the Contractor can incur any costs related to the use of the permit(s) for which the Contractor will request reimbursement.

**The Contractor shall:**

- Prepare a letter documenting the permits required to conduct this Agreement and submit it to the Energy Commission Contract Manager at least 2 working days prior to the kick-off meeting:
  1. If there are no permits required at the start of this Agreement, then state such in the letter.
  2. If it is known at the beginning of the Agreement that permits will be required during the course of the Agreement, provide in the letter:
    - A list of the permits that identifies the:
      - Type of permit

- Name, address and telephone number of the permitting jurisdictions or lead agencies
- Schedule the Contractor will follow in applying for and obtaining these permits.
- The list of permits and the schedule for obtaining them will be discussed at the kick-off meeting, and a timetable for submitting the updated list, schedule and the copies of the permits will be developed. The implications to the Agreement if the permits are not obtained in a timely fashion or are denied will also be discussed. If applicable, permits will be included as a line item in the progress reports and will be a topic at CPR meetings.
- If during the course of the Agreement additional permits become necessary, then provide the appropriate information on each permit and an updated schedule to the Energy Commission Contract Manager.
- As permits are obtained, send a copy of each approved permit to the Energy Commission Contract Manager.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the Energy Commission Contract Manager within 5 working days. Either of these events may trigger an additional CPR.

**Deliverables:**

- A letter documenting the Permits or stating that no Permits are required
- Updated list of Permits as they change during the Term of the Agreement
- Updated schedule for acquiring Permits as it changes during the Term of the Agreement
- A copy of each approved Permit

**Task 1.9 Electronic File Format**

The goal of this task is to unify the formats of electronic data and documents provided to the Energy Commission as contract deliverables. Another goal is to establish the computer platforms, operating systems and software that will be required to review and approve all software deliverables.

**The Contractor shall:**

- Deliver documents to the Energy Commission Contract Manager in the following formats:
  - Data sets shall be in Microsoft (MS) Access or MS Excel file format.
  - PC-based text documents shall be in MS Word file format.
  - Documents intended for public distribution shall be in PDF file format, with the native file format provided as well.
  - Project management documents shall be in MS Project file format.

- Request exemptions to the electronic file format in writing at least 90 days before the deliverable is submitted.

**Deliverables:**

- A letter requesting exemption from the Electronic File Format (if applicable)

**TECHNICAL TASKS**

The Contractor shall prepare all deliverables in accordance with the requirements in Task 1.5. Deliverables not requiring a draft version are indicated by marking “(no draft)” after the deliverable name.

**Task 2 Advanced Combined Cooling Heat And Power For Building Efficiency**

The goal of this task is to develop engineering tools for designing and operating combined cooling, heat and power (CCHP) systems by analyzing, optimizing and documenting performance of an existing CCHP system using natural gas-power fuel cells, liquid cooled photovoltaic cells, absorption cooling, heating, and thermal energy storage at the University of California Irvine (UCI).

**The Contractor shall:**

- Acquire dynamic data from a commercial absorption chiller, high temperature fuel cell, and solar power installations existing on the UCI campus, sufficient to characterize hourly behavior of each system with diurnal fluctuations in each season.
- Acquire corresponding data to characterize dynamics of electrical, heat and cooling demand of an existing representative campus building.
- Prepare a report on data acquired from fuel cell, absorption chiller, solar power installations and representative buildings.
- Prepare a report on engineering analysis tools for conceptualizing and designing integrated fuel cell, absorption chiller, and solar power installations for CCHP systems.
- Analyze the thermodynamics and dynamics of the chiller, fuel cell and solar power data.
- Develop tools for conceptualizing, analyzing and designing integrated absorption chiller, high temperature fuel cell, and solar power systems and prepare a report on the tools.
- Demonstrate the technical feasibility and economic viability of novel integrated fuel cell, absorption chiller, and solar CCHP systems. Prepare a report on technical and economic feasibility of the integrated system.
- Compile results of the activities within this task into a final project report titled “Advanced Combined Cooling Heat and Power for Building Efficiency” in the same format as the Final Report, detailed in Task 1.6.

**Deliverables:**

- Acquired Data Report (no draft)
- Engineering Analysis Tools Report (no draft)
- Technical and Economic Feasibility Report (no draft)
- Advanced Combined Cooling Heat and Power for Building Efficiency Report

**Task 3 Solar Thermal for Efficient Combined Cooling, Heat, And Power**

The goal of this task is to reduce non-renewable energy consumption in commercial buildings by developing and demonstrating the use of moderate-scale concentrating solar power (CSP) in combination with traditional natural gas-fired sources for CCHP systems.

**The Contractor shall:**

- Construct a previously designed prototype of a combined solar power/natural gas (CSP/NG) system with CHP or CCHP on California Polytechnic State University (Cal Poly), San Luis Obispo property.
- Provide a memorandum to the Energy Commission Contract Manager verifying construction of the prototype.
- Initialize and balance the system.
- Study issues and challenges of construction, balancing and commissioning solar distributed energy system.
- Prepare a report on the construction process, balancing system, and other issues and challenges of deployment.
- Compile results of the activities within this task into a final project report titled “Solar Thermal for Efficient Combined Cooling, Heat, and Power” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Prototype Memorandum (no draft)
- Construction Process, Balancing System, Issues and Challenges of Deployment Report (no draft)
- Solar Thermal for Combined Cooling, Heat, and Power Report

**Task 4 Improving Heating/Cooling Systems with Phase Change Materials**

The goal of this task is to improve the efficiency of residential hydronic space heating and cooling systems by researching the feasibility of adding encapsulated phase change material (PCM), such as paraffin and salt hydrate, to closed water circulation systems. These beads can increase the heat capacity of the water, allowing for a reduction in water flow rate for electric power savings, while increasing the heat transfer capacity of heat exchange systems.

**The Contractor shall:**

- Conduct a literature review and study of the fluid dynamics of the proposed system.
- Evaluate and select appropriate PCMs for further study.
- Conduct a study of existing pumping technologies and assess their suitability for use with PCMs.

- Prepare a report on literature review and PCM evaluation.
- Develop a test protocol for laboratory evaluation of performance of PCM based fluids.
- Design and select equipment for a prototype system.
- Build a laboratory test system.
- Prepare a report on experimental design for laboratory testing.
- Conduct a laboratory test of PCM based fluids.
- Disseminate results through the heating and air conditioning industry.
- Demonstrate the benefits of the proposed system to industrial partners and solicit support for further work.
- Prepare a report on hydronic cooling including laboratory test results and project conclusions.
- Compile the results of activities within this task into a final project report titled "Improving Heating/Cooling Systems with Phase Change Materials" in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Literature Review and PCM Evaluation Report (no draft)
- Experimental Design for Laboratory Testing Report (no draft)
- Hydronic Cooling, Laboratory Test Results and Conclusions Report (no draft)
- Improving Heating/Cooling Systems with Phase Change Materials Report

**Task 5 Mini-Channel Technology to Improve Solar Water Heaters**

The goal of this task is to design and manufacture a solar water heater with a mini-channel heat exchanger, and a round-tube flat-plate (RTFP) solar water heater, to demonstrate the improved performance of the former in relation to the latter, and to analyze the market for the technology and determine design changes needed to ease mass production of the mini-channel-based solar water heater.

**The Contractor shall:**

- Collect technical and operational information about tube sizes, coatings, insulation materials, casing, and glass covers available in the market.
- Design the mini-channel and similarly sized RTFP solar water heaters, along with test stands.
- Develop computational models of the two solar water heaters.
- Manufacture both water heaters and install experimental test set up.
- Prepare a report on design, computational model, and manufacture of both water heaters.
- Develop a four-season test plan, test the units to analyze possible improvements, validate computational models, and prepare report on test plan and test results.
- Perform a detailed evaluation of the market size.
- Determine design changes needed to mass-produce the unit.
- Prepare a report on market size and changes in the design and manufacturing process needed for mass production.

- Compile the results of activities within this task into a final project report titled “Mini-Channel Technology to Improve Solar Water Heaters” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Design, Computational Model and Manufacture of Water Heaters Report (no draft)
- Test Plan and Test Results Report (no draft)
- Market Size, Changes in Design and Manufacturing Process Report (no draft)
- Mini-Channel Technology to Improve Solar Water Heaters Report

**Task 6 Wireless Measurement Tools for Better Indoor Environments**

The goal of this task is to improve indoor environmental quality and reduce energy use by developing and promoting a standard toolkit for implementing the ASHRAE Performance Measurement Protocol (PMP) in existing and new buildings. The environmental attributes to be measured include radiant temperature, temperature stratification, humidity, lighting, acoustics, and air quality.

**The Contractor shall:**

- Develop system specifications for hardware and analysis and visualization software.
- Procure wireless hardware and supporting instruments aimed at conducting PMP Level-2 measurements.
- Design and implement a centralized data management and analysis system.
- Develop appropriate data analysis and visualization capabilities.
- Evaluate results from field-testing, recommend refinements, and assist in commercialization of the technology.
- Prepare a report on wireless PMP toolkit.
- Compile the results of activities within this task into a final project report titled “Wireless Measurement Tools for Better Indoor Environments” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Wireless PMP Toolkit Report (no draft)
- Wireless Measurement Tools for Better Indoor Environments Report

**Task 7 Saving Energy In Buildings with Adaptive Lighting Systems**

The goal of this task is to achieve energy and peak demand savings in California by developing and demonstrating adaptive lighting systems in retail and agricultural buildings. These lighting systems will ensure lights are off or dimmed when no occupants are present or when there is available daylight.

**The Contractor shall:**

- Identify retail spaces suitable for adaptive lighting systems using available data and, if necessary, computer simulation.
- Develop adaptive lighting solutions for selected retail and agricultural building spaces by integrating existing lighting technologies as well as, where necessary, developing prototypes of new technological solutions.



- Install and field-test adaptive lighting systems at retail and agricultural locations.
- Prepare a report on the design of the adaptive retail and agricultural lighting system and its field test performance.
- Compile the results of activities within this task into a final project report titled “Saving Energy in Buildings with Adaptive Lighting Systems” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Adaptive Lighting Systems for Retail and Agricultural Buildings Report (no draft)
- Saving Energy in Buildings With Adaptive Lighting Systems Report

**Task 8 Saving Energy In Buildings With Adaptive Envelope Systems**

The goal of this task is to achieve energy and peak demand savings in California by enabling widespread adoption of adaptive envelope systems in retail and agricultural buildings and optimizing their operation through integration with electric lighting and HVAC systems. Adaptive envelope systems, such as smart window and skylight systems, are systems that automatically adapt to environmental conditions such as temperature and solar radiation in order to minimize energy use.

**The Contractor shall:**

- Identify retail and agricultural spaces suitable for adaptive envelope systems using available data and, if necessary, computer simulation. Consider opportunities for cost-effective energy and peak demand savings.
- Develop adaptive envelope solutions for selected retail and agricultural spaces by integrating existing envelope technologies and, where necessary, developing prototypes of new technological solutions.
- Install and field-test adaptive envelope systems at retail and agricultural locations.
- Prepare a report on the design of the adaptive retail and agricultural envelope system and its field test performance results.
- Compile the results of activities within this task into a final project report titled “Saving Energy in Buildings with Adaptive Envelope Systems in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Design of Adaptive Retail and Agricultural Envelope System with Field Test Performance Results Report (no draft)
- Saving Energy in Buildings with Adaptive Envelope Systems Report

**Task 9 Improved Hvac Through Standards for Technician Instruments**

The goal of this task is to increase energy savings from utility programs by facilitating the adoption of more suitable instrumentation for HVAC installation and maintenance and suitable methods of using these instruments. Better instrumentation and technician training will improve energy performance of HVAC installations.

**The Contractor shall:**

- Establish an HVAC Technical Instrument Laboratory (HTIL) Advisory Committee.

- Review lab and field studies that document the link between instrument accuracy and maintenance quality. Visit labs performing similar functions.
- Identify human factors incorporated into measurements, establish priority list for testing products, and propose test procedures for each product.
- Identify requirements for instrument accuracy and measurement methods.
- Develop requirements for, build, and commission the HVAC Technician Instrument Laboratory.
- Prepare a report on activity up through building and commissioning of the HTIL.
- Develop online resources to compare manufacturers' report data and discuss measurement methods.
- Engage in development of standards for field measurements and instrumentation.
- Test and report on suitability of multiple makes and models of instruments to measure pipe temperature, duct air temperature, duct air humidity, duct airflow, and refrigerant pressure.
- Test the effects of human factors on measurements and develop best practices for making measurements.
- Prepare a report on testing of instrumentation, including human factors.
- Disseminate results, hold trainings, and integrate results with utility training curriculum on measurement best practices. Prepare a report on dissemination and training activity.
- Prepare a technical paper on results presented at ASHRAE.
- Prepare a report on Standards for HVAC Technician Instruments.
- Compile the results of the activities within this task into a final project report titled "Improved HVAC Through Standards for Technician Instruments" in the same format as the Final Report detailed in Task 1.6.

#### **Deliverables:**

- Commissioning HVAC Technician Instrument Laboratory Report (no draft).
- Testing Instrumentation, Including Human Factors Report (no draft)
- Dissemination and Training Activity Report (no draft)
- Technical Paper on ASHRAE Results (no draft)
- Improved HVAC Through Standards for Technician Instruments Report

#### **Task 10 Improving HVAC Electric Motor Systems in Buildings**

The goal of this task is to reduce electrical energy use in California's buildings by evaluating HVAC drive and other motors and quantifying energy waste due to use of lower efficiency motors, use of oversized motors, and selection of oversized motors in the architectural and engineering design stage of new buildings.

#### **The Contractor shall:**

- Review current HVAC motor systems and Variable Frequency Drives (VFD) in use in buildings including literature review.
- Evaluate and analyze commercial and in-house software used by architectural and engineering firms designing HVAC systems for inflated safety factors used in calculating three-phase motor sizes for buildings.

- Prepare a report on software used by architectural and engineering firms to design HVAC systems.
- Adapt suitable power meters for high voltage and current HVAC motor power measurement.
- Measure energy use of on-site HVAC motor systems.
- Quantify over sizing of motors based on measurements and use statistical analysis to project total impact for California.
- Prepare a report on HVAC motor systems in use, modified meters, and data on oversized motors and impact on California.
- Set up a large motor testing facility at the University of California Riverside (UCR) that can test new and old HVAC motors, VFDs and Adjustable Speed Drives and conduct workshops in order to promote its availability.
- Prepare a report on capabilities of large motor testing facility at UCR including test results on a few sample motors.
- Compile the results of activities within this task into a final project report titled Improved “Improving HVAC Electric Motor Systems in Buildings” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Software Report (no draft)
- HVAC Motor Systems Report (no draft)
- UCR Motor Report (no draft)
- Improving HVAC Electric Motor Systems in Buildings Report

**Task 11 Enabling Renewable Fuels Through Flexible Burners**

The goal of this task is to develop and demonstrate the overall feasibility of a fuel flexible burner system that will respond to operating impacts associated with changes in fuel composition and to adjust its performance accordingly. Flexible fuels may include such fuels as unprocessed natural gas, coal bed methane, landfill and digester gas, syngas, and hydrogen.

**The Contractor shall:**

- Establish 400 kW and 4 MW bench scale burner facilities platforms with which to evaluate fuel flexible burner concepts required to monitor and compensate for fuel composition variation. Burners will be developed and tested that can vary operational characteristics to facilitate control, including multiple fuel circuits or ability to vary flow splits.
- Establish a robust sensing methodology for either fuel composition or reaction characteristics that is sensitive to the impact of fuel composition.
- Prepare a report documenting burner geometry, sensor approach, and test plan.
- Map the performance of the bench scale burner and sensor(s) to controlled variation in fuel composition for use in the development of control algorithms. Analyze and correlate results.

- Prepare a database of relevant and measurable renewable and fossil fuel characteristics, and correlate the results with combustion behavior.
- Prepare a report on the database and correlation results.
- Establish a means to complete closed loop control of the burner using the information from the sensors gathered.
- Develop a commercialization plan.
- Prepare a report demonstrating closed loop control and plan for commercialization.
- Analyze the results obtained using fuel interchange parameters being developed under an ongoing program and use the burner platform to validate/confirm the parameters developed.
- Prepare a report on validation and application of fuel interchange parameters.
- Compile the results of activities within this task into a final project report titled Improved “Enabling Renewable Fuels Through Flexible Burners” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Burner Geometry, Sensor Approach, and Test Plan (no draft)
- Database and Correlation Results Report (no draft)
- Demonstrating and Commercialization Report (no draft)
- Validation and Application Report (no draft)
- Enabling Renewable Fuels Through Flexible Burners Report

**TASK 12 Increasing Renewable Energy By Almond Shell Gasification**

The goal of this task is to facilitate the use of clean fuel gas from the gasification of almond shell bi-product by optimizing the gasification process, developing advanced gas cleaning methods to reduce tar levels, and reducing exhaust emissions when the fuel gas is combusted.

**The Contractor shall:**

- Characterize the thermo-chemical properties of almond shell by-product.
- Establish gasification characteristics of almond shell bi-product at laboratory scale on the 10 pounds/hour fluidized bed reactor at UC Davis, and at pilot scale on the 5 ton per day dual fluidized bed research reactor/power production system at the Woodland Biomass Research Center.
- Prepare a report on the thermo-chemical properties of almond shell by-product and the energy and material balance analysis of almond shell biomass from gasification experiments.
- Investigate a partial oxidation (POX) method to reduce tars, an undesirable by-product, in the fuel gas produced by almond shell by-product gasification at the UCD laboratory and at the Woodland Biomass Research center pilot scale research reactor.
- Prepare a report on the performance of POX on the tar reforming and the removal of tars from the fuel gas.
- Develop and evaluate new catalyst formulations and emission control systems in order to optimize the performance of a three-way catalytic converter. This will

minimize combustion exhaust emissions of nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) in order to meet CARB emission requirements in an eight cylinder Waukesha H-2475G Spark Ignition engine. The 120- kW engine is used for power production at the Woodland Biomass Research Center.

- Prepare a report on the performance of the three-way catalytic converter and how well it meets the CARB requirements.
- Compile the results of activities within this task into a final project report titled “Increasing Renewable Energy by Almond Shell Gasification” in the same format as the Final Report detailed in Task 1.6.

**Deliverables:**

- Almond Shell By-Product and Gasification Characteristics Report (no draft)
- Tar Reforming and Tar Removal Report (no draft)
- Catalytic Converter and Emission Reduction Report (no draft)
- Increasing Renewable Energy by Almond Shell Gasification Report